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THE HISTORY AND FUTURE OF RICE CULTIVATION IN HOKKAIDO

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CONTENTS

INTRODUCTION

Apart from the fact that carbonized rice has been excavated from soil strata dating back some two thousand years along the Pacific coast of Kyushu and neighbouring Japanese islands to the southwest as well as the Chubu area of Honshu, it is not known when and by what route rice came to Japan and came to be grown here on a regular basis. From this fact, however, it can at least be said that there had already been contact with rice by that time. If one were to conjecture the areas of Japan in which rice was then grown, the northern limit must have been where the mean annual temperature was 14-15°C, assuming that the climate then was the same as today. In other words, such present major rice-growing areas as the Hokuriku area, the Kanto area, and the Tohoku area were completely outside that sphere. It took more than a thousand years for rice cultivation subsequently to spread over all of Honshu. That was how long it took for rice cultivation to extend as far north as areas with an average annual temperature of 11-12°C. In spite of this northward march of rice cultivation, however, up until about 120 or 130 years ago there was no agriculture at all, let alone rice cultivation, on Hokkaido, Japan's northernmost island.

In 1868 the large-scale civil war that Japan was experiencing at that time reached its climax, and in the following years many people, mostly those on the losing side, had to go to Hokkaido to try to make new lives for themselves. This land of heavy snowfalls, situated on a latitude between 41°18' and 45°30' north, has an average annual temperature of about 5°C, except for its southwest corner where the average annual temperature is about 6-8°C, and is free from frost only about half the year and only about four months in its northeastern area. With no rice cultivation or any other kind of agriculture, the

first settlers had to rely on shipments of food from Honshu. A number of difficulties, however, stood in the way of such supply, not the least of which was the closing of snow-bound transportation routes in the winter months. The situation became so critical that the settlers realized that their only recourse was to develop permanent agriculture locally, no matter what trials and tribulations they would have to go through in this inhospitable environment.

Nowadays farmers in Hokkaido can count on a yield of unpolished rice of over four tonnes per hectare, which is about average for Japan as a whole. The development of rice cultivation in Hokkaido is unique in that it was only very recently that the creativity and effort of so many people began to fill in what can be likened to a blank sheet of paper, first with lines and then over whole stretches of land. I should like here to describe briefly how the settlers of Hokkaido overcame their harsh natural environment and how the knowledge and wisdom that was gained in the process have contributed to rice cultivation in other countries as well, with emphasis on the breeding of varieties and cultivation techniques, in the hope that such a description might be helpful in considering the future development of agriculture.

I. THE BEGINNINGS OF RICE CULTIVATION IN HOKKAIDO

If the planting of even one stalk of rice can be considered the beginning of rice cultivation in Hokkaido, there is a record of an attempt by a local settler to plant this crop in the southernmost area in 1685. In those days that was about the only area of Hokkaido that people were living in permanently, this being on the basis of fishing alone, since as yet no agriculture whatsoever had developed. After that first attempt many others followed, with varieties from all over Honshu and particularly the Tohoku area being tried, as well as natural varieties being sought in the northern frontier lands them-

selves, and over a period of two hundred years several promising varieties were discovered. Although by present-day standards they would hardly be considered varieties as such, they were the prototypes from which the early-period rice varieties of the southern extremity of Hokkaido were developed, through individual and collective experimentation and effort, in the soil from which Hokkaido rice cultivation subsequently evolved. In other words, they were the valuable materials on which subsequent rice breeding was based. They did not, moreover, derive from well-known Honshu varieties. Rather, they were discovered among the large number of wild mountain varieties to which no one had paid any attention. The people who discovered them were the first rice farmers of Hokkaido, and they prepared the way for the establishment of Hokkaido varieties of rice. In 1870 Japan began to have exchanges with the outside world on a large scale. This was the start of the period of inflow of western culture, a period in which Japan looked to the advanced countries of the West in almost every respect. It was only natural, therefore, that the Japanese government of that time should have considered an American adviser necessary for the task of developing Hokkaido, and it got one in 1871, in the person of United States Agriculture Secretary Capron, after having asked President Grant to find someone suitable. A team of American advisers headed by him was sent to Hokkaido to study the situation. When asked what, in their opinion, would be possible in the way of agriculture on Hokkaido, they answered that the area was not suitable for rice cultivation and that the orientation of agriculture should be toward other field crops. In those days that opinion seemed to make sense, and it was much quoted in debate on the question of Hokkaido agriculture. In a sense, in fact, it remains a viable opinion in that the important question of what the agriculture of Hokkaido should be like in the future is still an open question.

Nevertheless, this opinion did not succeed in extinguishing enthusiasm for development of rice cultivation in Hokkaido. Furthermore, it was mainly settler farmers themselves, and some people working for the government agency for the development of Hokkaido who were impressed by their enthusiasm, who quietly continued efforts in this respect

without any government protection or cooperation.

The main geographical factor in agriculture is climate. Let us therefore compare the climate of Hokkaido with that of other parts of the world. The average annual temperature at Sapporo, the seat of the prefectural government, is a low 7.5°C. Furthermore, as can be seen in figure 1, the seasonal temperature variation is much more pronounced than not only such subtropical and tropical areas as Taipai, Manila, Penang, and Bangkok, but also Tokyo. Nevertheless, fairly high temperatures are reached during the short summer period, the average between early summer (May) and early autumn (September) being 16°C in southwest Hokkaido, 15°C in eastern Hokkaido, and 14°C in northern Hokkaido. With present experience and technology, such temperatures are not so low as to rule out the possibility of rice cultivation. The fact remains, however, that if the temperature should fall below this level for as briefly as four or five days during the summer, considerable damage would be done to the rice crop. Furthermore, the shortness of the frost-free period sets severe limits on the growing season.

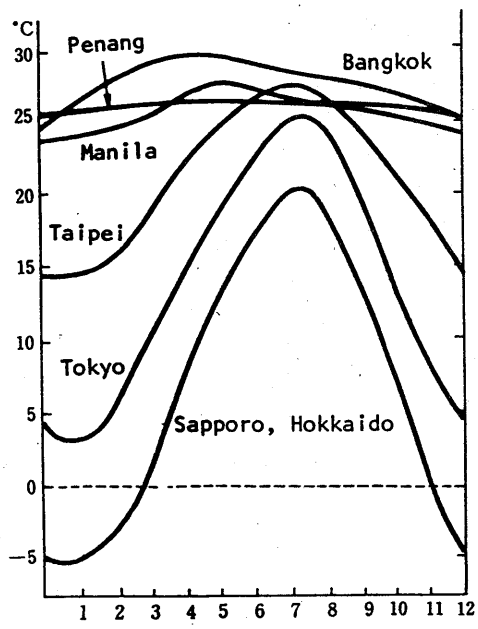

FIG. 1. Average Monthly Temperature of Different Rice-Cultivating Locations

This is inevitable in any high latitude area. One must ask oneself, however, whether the conditions to be found in high latitude areas are all to the disadvantage of rice cultivation. One should not forget that the higher the latitude, the longer summer days are. At Sapporo they are more than 15 hours long, three hours longer than in tropical areas. That means extra time for the all-important process of photosynthesis, a distinct physiological advantage. Furthermore, the short, cooler nights mean less consumption, during nocturnal breathing, of the dry matter produced by photosynthesis during the day. In short, this presents good possibilities for rice cultivation in Hokkaido. Another natural advantage that Hokkaido has to offer is in terms of water for irrigation, since it has many mountain ranges running in different directions which afford a plentiful water supply when the snow begins to melt in the spring. In other words, shortage of water is not a constraint on agriculture as it is in so many other parts of the world.

The only remaining problems, therefore, are how to keep the whole growth period of the rice within the relatively short frost-free period, how to obtain the young rice plants for transplanting, and how to minimize possible damage due to unpredictable spells of abnormally low temperature in the summer. Back in those days, however, the situation looked much less promising.

II. EXPANSION OF ACREAGE AND MOVEMENT NORTHWARD

The first trial growth of the Akage variety, generally considered the forerunner of the Hokkaido rice varieties and originally selected by farmers, was voluntarily undertaken by Kyuzo Yamanaka on the Ishikari Plain in 1873. The results showed that it was a variety characterized by adequate early growth and resistance to cold. This was an epoch-making discovery and in the following years a fair acreage of rice

cultivation was realized on the inland part of that plain. The yield in those days was 1.5 tonnes of unpolished rice per hectare, which indicated that this was a viable local variety basically acclimatized to conditions in Hokkaido. Furthermore, as a result of this success, the government agency for the development of Hokkaido for the first time retracted its critical attitude toward rice cultivation in Hokkaido, and in 1893 it established an area on the outskirts of Sapporo for test growth of different varieties.

The initial technical development tendencies in rice farming in Hokkaido, the viability of which had already been demonstrated by farmers themselves, were first, the establishment of a method of growth management, including application of fertilizer in the early phase of growth, which was completely different from that employed on Honshu; and, second, the extraction of individual specimens or lines of early growth and of cold-resistance characteristics through large-scale selection from among existing varieties. It was not long before a solution was reached with respect to the former: that of directly sowing instead of transplanting. This was a very good idea in view of the fact that, in the spring, air temperatures tend to be lower than water temperatures in Hokkaido. For many years before the appearance of modern varieties it also made a great contribution to the prevention of crop damage due to cold, in that it helped to keep the growth period within the bounds set by the frost-free period. As for the second tendency, the existing varieties that were at first adopted in Hokkaido did not represent any particular breeding, and in spite of the variety of names given them, they should be considered to have been mixtures of a number of different lines. At the same time as being a shortcoming, however, this also meant that they could be used as materials for breeding through extraction of pure lines and, sure enough, expectations were fulfilled with the extraction first of Akage and then of Bozu, Sakigake, and other early growth lines, many of which, needless to say, were used as new varieties in extending the rice belt northward (see table 1).

The theory of pure-line separation, in the present-day science of

TABLE 1. Number of Select Rice Varieties of Hokkaido (excluding glutinous rice)

	Before 1890	1891-1910	1911-1930	1931-1950	1951-1970	After 1970	Total
Existing varieties selected by farmers	4	5	4				13
Pure-line separation varieties bred by experimental stations			10				10
Crossbred varieties by experimental stations			3	28	37	2	70
	4	5	17	28	37	2	93

breeding established in the period 1910-1927, is based on Johanssen's pure-line theory. In Hokkaido, however, pure-line separation had already been deliberately used in practical breeding. Furthermore, only three years after the rediscovery of Mendel's laws of heredity in 1900, experimental research in this field was undertaken in Hokkaido in full awareness of these laws, and it was only 12 years later that a start was made in Hokkaido on crossbreeding rice in a deliberate attempt to regroup genes. Moreover, with the help of this new knowledge, the many lines and varieties in use in Hokkaido became new materials for crossbreeding, their use thereby being increasingly broadened. This was the period, extending from 1913 to 1925, of crossbreeding between Hokkaido varieties. Thus better varieties were created from combinations of many, including combinations of Akage, Bozu, Sakigake, and other varieties. The cold resistance of Akage and the early maturation of Bozu and Wase-bozu were passed on to many later varieties in different forms, and in this period the extremely early growth variety Hashiri-bozu was obtained by crossbreeding Sakigake with Bozu. In fact, both it and the later Norin No. 11 were among the earliest-maturing varieties in the world.

In 1927 Honshu varieties began to be crossbred with Hokkaido varieties for the purpose of widening the range of hereditary variation and obtaining various characters that would help to improve varieties and yield. It was thanks to the theorization by Garner in 1920 of photoperiodic phenomena of plants that it became possible to use early-maturing Honshu varieties in such crossbreeding by controlling the

timing of heading (flowering), through the day-length treatment technique. Research on the photoperiodic characteristics of rice began in 1926, and as early as 1929 the results of such research began to be applied in actual breeding in Hokkaido ahead of all other areas of Japan.

As a result of the appearance of Bozu and other varieties in the same line, the boundary of the rice cultivation belt in Hokkaido moved northward faster than anyone might have expected. Figure 2 shows the relation of the appearance of new varieties to the expansion of rice acreage and such northward movement, the map on the left side showing mean temperatures in July and August and that on the right side the northward march of the Hokkaido rice belt as based on the introduction of improved varieties. As can be seen, there was perfect consistency between isothermal lines and the appearance of the new varieties, which convincingly attests to the fact that the main factors determining the geographical limits of the rice belt in Hokkaido were the degree of early maturation and the degree of resistence to cold.

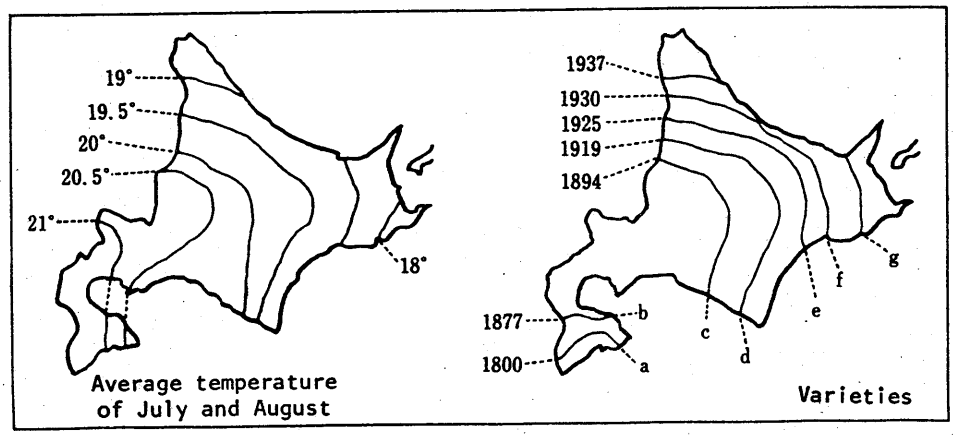

FIG. 2. Climate and Expansion of Rice Cultivation in Hokkaido

a: existing varieties
b: Akage
c: Bozu
d: Improved Bozu
e: Bozu No. 6
f: Hashiri-Bozo
g: Norin No. 11

III. PROTOTYPES OF MODERN HIGH-YIELD VARIETIES

People began to have doubts and second thoughts, however, about the wisdom of such a rapid expansion of the rice belt northward when the new problem of frequent crop damage due to cold and rice blight arose. Fortunately, however, new varieties were created to dispel these doubts, most notably the Fukoku, Eiko, and Norin No. 20 varieties.

These varieties were characterized by lower stature, more sprouts, shorter spikes, and more upright stance than earlier varieties, such characteristics being close to the morphological requirements of the heavily fertilized, high-yield rice that has become so widely known today. One might ask whether or not people in those days noticed or had a presentiment about the nutritional significance of such morphological characteristics for a crop. Unfortunately, they did not. Since there was frequent rice blight owing to the use mainly of herring, soya bean, and rape-seed draff as fertilizer, and the high-standing traditional varieties were easily flattened, both resulting in considerable harvest losses, farmers were anxious, above all, to use varieties with shorter stalks. It was not until considerable use came to be made of chemical fertilizers, when a switch was made to transplanting instead of direct sowing and rice came to be planted more densely with the development of hothouse growth of young rice plants, that it became apparent that these morphological characteristics were in fact directly conducive to higher yields. They were not necessarily advantageous in terms of individual stalks, but, as is clear in the light of present breeding, nutrition, and physiological theory, they made for a three-dimensional structure of densely standing growths that allowed for greater efficiency of photosynthesis than in the case of earlier, less densely grown varieties. This is indicated diagrammatically in figure 3. The Fukoku and Eiko varieties [meaning "national prosperity" and "glory," respectively] indeed stand out in the history of Japanese rice breeding.

Since the development of the Fukoku variety, rice breeding in Hokkaido

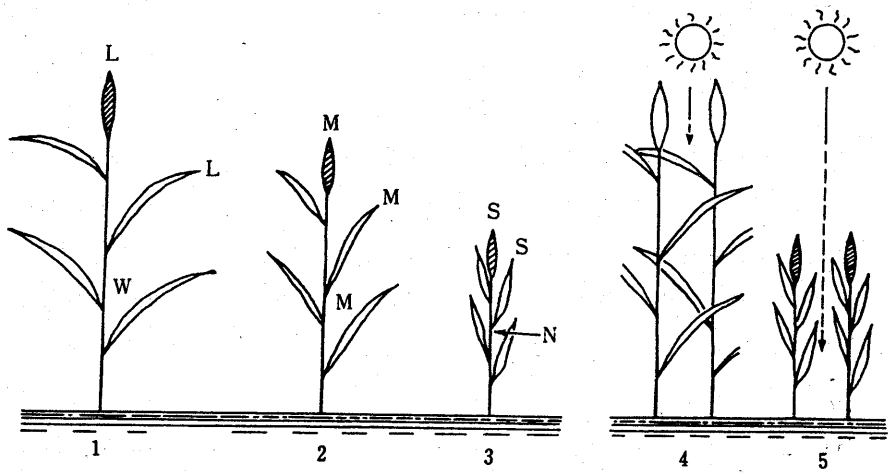

FIG. 3. Morphological Characteristics of Different Varieties

1, 2, and 3: show stances of the existing Indica variety, the improved Indica variety, and an improved variety of Hokkaido respectively

4 and 5: show the leaf arrangement of 1 and 3. 4 shows that lower leaves are in the shade of upper leaves and have lower photosynthetic rates

W, M, and N: indicate "wide," medium," and "narrow" leaf blade angles respectively

L, M, and S: indicate "long," "medium," and "short" spikes and stems respectively

has been attempting to make up for certain deficiencies while moving in the same direction as before. In fact, the same can be said of rice breeding throughout Japan, and I therefore do not intend to elaborate on the matter since this paper is concerned only with rice cultivation in Hokkaido. I would like to point out, however, that at times rice crop yields have tended to be as high throughout Japan as in northern areas of the country, a very good indication of the speed with which new varieties were adopted.

IV. CONTRIBUTION TO DEVELOPMENT OF NEW INTERNATIONAL VARIETIES

In the fine tradition of Hokkaido rice breeding as outlined above, a Hokkaido breeder in 1964 successfully developed the Malinja and Mahsuri varieties in Malaysia, which became famous for their use there

as second crops. Such use is one way in which that country can increase its food self-sufficiency, made possible by combining reliable irrigation technology with varieties of rice that grow in a relatively short period of time, and we have already seen how the Bozu and Hashiri-bozu varieties of Hokkaido met this requirement of early maturation.

Furthermore, the International Rice Research Institute and others were aware of the true value of the initial morphological features of Hokkaido varieties. In 1966 and 1967 that institute announced the new high-yield varieties IR-8 and IR-5, which for a time were hailed as "miracle rice." Under favourable conditions, such as those at agricultural testing stations and in the fields of farmers who volunteered to try them, they registered yields of six to seven tonnes per hectare, which is remarkable considering that the average for Southeast Asian countries is one to two tonnes and that for Japan, known for its high yields, is only 4.5 tonnes.

Traditional varieties grown in Southeast Asia with traditional farming techniques are generally characterized morphologically by long stalks, a large number of stems, broad and open leaves, and vigorous nutritional growth, making for more straw than paddy. These features were produced as a long historical process of adaptation in which rice, growing in paddy fields directly dependent on rainfall and without any fertilizers, struggled against vigorously growing weeds for survival over thousands of years. If this kind of rice is treated with fertilizer, it will overgrow and fall over under its own weight. For a time, therefore, it was mistakenly believed that it was impossible to improve rice cultivation in such areas since yield would not increase to the extent that fertilizer was applied and could even be less than without fertilizer. Hokkaido varieties, however, furnished the hint as to the solution of this problem, and it at last dawned on the world that here were the prototypes for more modern varieties.

IR-8 differed from earlier varieties in that it was designed for limited nutritional growth, which meant that it would not easily fall over even with heavy application of fertilizer. This was achieved by

combining the physiological capacity of an Indonesian variety with the shortness of stalk of a Taiwanese variety. Because of its characteristic erect structure, sunshine reached all the way to its lower leaves for more efficient use of solar energy, and in addition fertilizer could be heavily applied for increased yield without having to worry about the rice lying down because of overweight. Furthermore, yield was increased still further owing to this variety's good photosynthetic capability even after flowering. And over and above these advantages, it also offered the possibility of growing three crops a year, provided there was adequate irrigation water, since its early maturation meant a full growth period of only about 120 days and its sensitivity to light was low. Furthermore, it represented an improvement in the ratio of paddy to straw to 1.6 from the 0.6 of traditional varieties.

You can imagine how the news of this new variety was received by developing countries that had for so long been unable to raise their rice crop yields. In fact, many of them lost no time in drawing up plans for an increase in production on the basis of the introduction of this new variety. In practical terms, however, were their circumstances such as to allow for its successful introduction? The following were some of the problems they faced in this respect:

1. Short-stalk varieties are small when young and therefore can only be planted in paddy fields with shallow water, which means that irrigation and drainage facilities must be adequate.
2. Since deep water protects against field mice and weeds, shallow water cultivation has to be accompanied by other means of accomplishing the same thing.
3. An eight to nine tonne harvest of IR-8 requires the application of 120-150 kg of nitrogen fertilizers, and that means a considerable expenditure.
4. IR-8 has low resistence to bacterial blight disease, which is widely distributed in Asia, and the incidence of this disease is raised by application of fertilizer.
5. With this variety, the rice grains are easily broken during polishing.

These drawbacks are all now generally recognized, which makes IR-8 a far cry from the "Green Revolution" that there was so much talk about a while back.

It may not have been exactly a "Green Revolution," but neither was it a complete failure. It seems to me that it would have been wiser to consider such new varieties as Malinja and IR-8 as a first milestone along the way to modernization of Asian agriculture than to consider them in isolation as the varieties that should be used to increase rice production in this area of the world. Thanks to the appearance of these high-yield varieties and the commotion that they stirred, however, the factors that will have to be taken into account in the improvement of agriculture in developing countries have been set in relief. Among these factors are flood prevention, infrastructural improvement of farmland (including irrigation and drainage), supply routes for fertilizers and farm chemicals, the purchasing power of farmers, intensive labour input, and improvement of storage and marketing of farm produce, many of which involve concrete problems. As a matter of fact, since then a number of new and more suitable varieties have been developed for different areas on the basis of an awareness of such problems.

CONCLUSION

To return to rice cultivation in Hokkaido, one of the biggest problems that still remains is that of improving resistance to cold through breeding, since there is still considerable crop damage due to cold. In fact, the rice crop has been hit by cold 25 times in the past century, an average of once every four years. In Hokkaido there are two types of damage due to cold. The first type is one in which growth and flowering are delayed by low temperatures over a long period or full maturation is impeded by low autumn temperatures. The

second is one in which maturation is prevented by low temperatures in mid-summer, the reproduction and growth season when there is greatest sensitivity to cold, which impede pollination. Considerable damage would be caused, for instance, by only five days of temperatures below 15°C in mid-summer. Furthermore, low temperatures increase damage due to blight since they reduce resistance to it.

I will not go into detail, but would like to point out that basic research on this problem is continuing and that everything is being done to cope with it. Nevertheless, as can be seen in figure 4, cold kept the yields down to 2.5 tonnes per hectare in 1945 and 1965, for instance, the same level as back in 1925, when it was considered a bumper yield. In 1945, however, it was just average, and in 1965 it was a bad harvest.

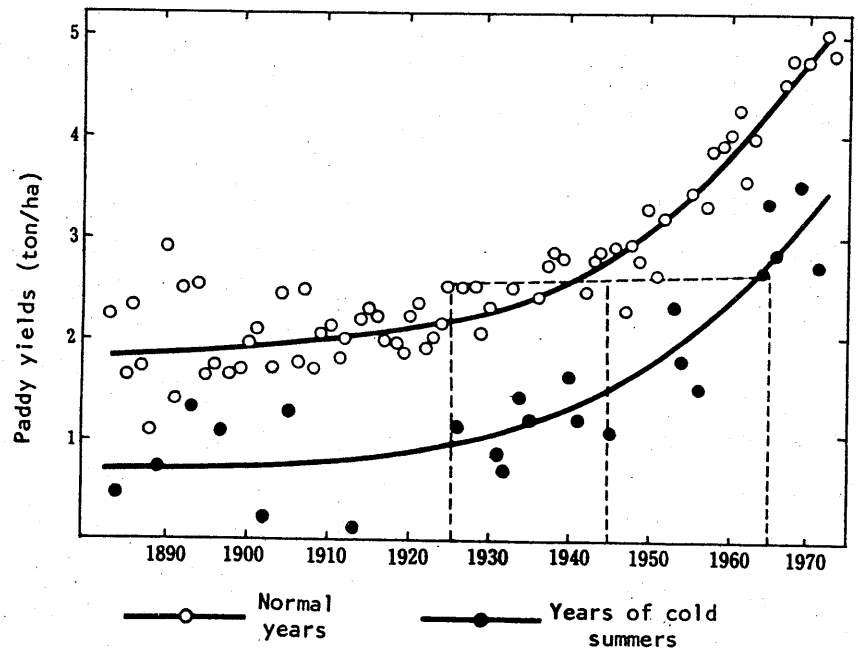

FIG. 4. Rice Yields of Hokkaido over the Past 90 Years

As we have seen, rice cultivation in Hokkaido has contributed immensely to the improvement of rice cultivation technology throughout the world, the reason being that, in warmer and even tropical areas of the world, rice has come to be grown under lower temperatures as paddy fields have been developed at higher elevations, and the period of rice cultivation has lengthened with the introduction of two or even three

crops a year.

In any case, it is a wonderful thing that the rice which came to Japan thousands of years ago, and which in the last hundred years has become the main agricultural crop of even that northern frontier land Hokkaido, is now, like a local boy made good, going back to its original home in tropical areas in an immensely improved form.

POSTSCRIPT

The following papers econometrically analyze basic research, breeding technology, and development of new varieties, and the direction that such development has taken with respect to rice cultivation in Japan, as well as describing future prospects and identifying remaining problems. Although a little overtechnical, they are highly commendable from the standpoint of clearly defining the importance of variety improvement to agriculture and contributing to the setting of breeding goals, i.e. to the determination of breeding strategy:

Seiji Sakiura, "Factors Influencing Wet Rice Variety Improvement," Agricultural Economic Research, vol. 46, no. 3, 1974.

Seiji Sakiura, "Wet Rice Variety Improvement and Selection Since the War," Collection of Papers on Agricultural Economics, vol. 31, 1974.

Seiji Sakiura, "Patterns of Adoption of Improved Varieties Since the War," Collection of Papers on Agricultural Economics, vol. 32, 1976.